

Appl. No. 10/707,989  
Response dated April 11, 2005  
Reply to Office Action of Jan. 11, 2005

The following listing of claims will replace all prior versions, and listings, of claims in the application.

**LISTING OF CLAIMS:**

1. (original) A plasma processing apparatus for performing plasma processing with respect to a sample to be processed in a reaction vessel, comprising:

microwave generating means that generates microwaves;

a first dielectric that is connected to the microwave generating means, the first dielectric having a rectangular section that extends along the surface of the sample to be processed, and which makes an electric field strength distribution of the microwaves generated from the microwave generating means substantially uniform along the surface to be processed of the sample;

a slot plate that is provided between the reaction vessel and the first dielectric and having a plurality of first slots formed therein, the slot plate maintaining or further enhancing the uniformity of the electric field strength distribution of the microwaves in the first dielectric;

a second dielectric that is provided between the slot plate and the reaction vessel and which maintains or further enhances the uniformity of the electric field strength distribution of the microwaves supplied from the slot plate; and

processing means that processes the sample using plasma generated in the reaction vessel by the microwaves.

2. (original) The plasma processing apparatus according to claim 1, wherein

a section of the second dielectric that extends along the surface of the sample to be processed is rectangular.

3. (original) The plasma processing apparatus according to claim 1, wherein

the reaction vessel is formed such that a section thereof that extends along the surface of the sample to be processed is rectangular.

4. (original) The plasma processing apparatus according to claim 1, wherein

Appl. No. 10/707,989  
Response dated April 11, 2005  
Reply to Office Action of Jan. 11, 2005

the microwave generating means include an antenna in which a section that extends along the surface of the sample to be processed is rectangular, and the antenna is in contact with the first dielectric.

5. (original) The plasma processing apparatus according to claim 1, wherein

the size and shape of the first slots are substantially the same and are arranged in substantially the same direction, and a distance  $L_1$  between centers of adjacent first slots substantially satisfies the equation  $L_1 = n_{L1}\lambda_1$ , in which  $\lambda_1$  represents the wavelength of microwaves in the first dielectric and  $n_{L1}$  represents an integer of 1 or more.

6. (original) The plasma processing apparatus according to claim 1, wherein

the first slots have substantially the same size and the same shape, and are arranged in a linearly symmetrical manner with respect to either one of two axes that extend along the slot plate and orthogonal to each other, and a distance  $L_2$  between centers of adjacent first slots substantially satisfies the equation  $L_2 = n_{L2}(\lambda_1/2)$ , in which  $\lambda_1$  represents the wavelength of microwaves in the first dielectric and  $n_{L2}$  represents an integer of 1 or more.

7. (original) The plasma processing apparatus according to claim 1, wherein

two opposing sides of the first dielectric are parallel in a direction that extends along the surface of the sample to be processed, and a distance  $L_{d1}$  between the two opposing sides of the first dielectric substantially satisfies the equation  $L_{d1} = n_{d1}(\lambda_1/2)$ , in which  $\lambda_1$  represents the wavelength of microwaves in the first dielectric and  $n_{d1}$  represents an integer of 1 or more.

8. (original) The plasma processing apparatus according to claim 2, wherein

two opposing sides of the second dielectric are parallel in a direction that extends along the surface of the sample to be processed, and a distance  $L_{d2}$  between the two opposing sides of the second dielectric substantially satisfies the equation  $L_{d2} = n_{d2}(\lambda_2/2)$ , in which  $\lambda_2$  represents the wavelength of microwaves in the second dielectric and  $n_{d2}$  represents an integer of 1 or more.

9. (original) The plasma processing apparatus according to claim 7, wherein

a dielectric constant of the first dielectric is substantially the same as that of the second dielectric.

Appl. No. 10/707,989  
Response dated April 11, 2005  
Reply to Office Action of Jan. 11, 2005

10. (original) The plasma processing apparatus according to claim 3, wherein  
two opposing sides of the reaction vessel are parallel in a direction that extends along the surface of the sample to be processed, and a length  $L_{p1}$  of the two opposing sides of the reaction vessel substantially satisfies the equation  $L_{p1} = n_{p1}(\lambda_p/2)$ , in which  $\lambda_p$  represents the wavelength of microwaves in the reaction vessel and  $n_{p1}$  represents an integer of 1 or more.
11. (original) The plasma processing apparatus according to claim 2, wherein  
two opposing sides of an introduction surface that is in contact with the first dielectric of the microwave generating means are parallel, a plurality of second slots through which the microwaves are introduced from the microwave generating means to the first dielectric are provided in the introduction surface, the central positions of the second slots are alternately arranged on two axes along the two opposing sides of the introduction surface, and a distance  $L_5$  between the two axes substantially satisfies the equation  $L_5 = n_{L5}(\lambda_1/2)$ , in which  $\lambda_1$  represents the wavelength of microwaves in the first dielectric and  $n_{L5}$  represents an integer of 1 or more.
12. (original) The plasma processing apparatus according to claim 11, wherein  
a distance  $L_4$  in an axial direction between centers of the second slots alternately arranged on the two axes substantially satisfies the equation  $L_4 = n_{L4}(\lambda_1/2)$ , in which  $\lambda_1$  is the wavelength of microwaves in the first dielectric and  $n_{L4}$  is an integer of 1 or more.
13. (original) The plasma processing apparatus according to claim 11, wherein  
a distance  $D1$  between end faces that extend along the two opposing sides of the introduction surface of the first dielectric and the two axes substantially satisfies the equation  $D1 = n_{D1}(1/4) \lambda_1$ , in which  $\lambda_1$  represents the wavelength of microwaves in the first dielectric and  $n_{D1}$  represents an integer of 1 or more.
14. (original) The plasma processing apparatus according to claim 1, wherein  
a thickness of the slot plate is 1 mm or more.
15. (original) The plasma processing apparatus according to claim 14, wherein  
a thickness of the slot plate is 3 mm or more.

Appl. No. 10/707,989  
Response dated April 11, 2005  
Reply to Office Action of Jan. 11, 2005

16. (original) The plasma processing apparatus according to claim 14, wherein  
the first slots of the slot plate are rectangular, and a length  $L_7$  of longer sides of the first slots substantially satisfies the equation  $L_7 \geq (3/8) \lambda_1$ , in which  $\lambda_1$  represents the wavelength of microwaves in the first dielectric.
17. (original) The plasma processing apparatus according to claim 16, wherein  
the length  $L_7$  of the longer sides of the first slots substantially satisfies the equation  $L_7 \geq (1/2) \lambda_1$ , in which  $\lambda_1$  represents the wavelength of microwaves introduced to the slot plate.
18. (original) The plasma processing apparatus according to claim 17, wherein  
the length  $L_7$  of the longer sides of the first slots substantially satisfies the equation  $L_7 = (1/2) \lambda_1$ , in which  $\lambda_1$  represents the wavelength of microwaves introduced to the slot plate.
19. (original) A plasma processing apparatus for performing plasma processing with respect to a sample to be processed in a reaction vessel, comprising:  
microwave generating means for generating microwaves;  
a first dielectric that is connected to the microwave generating means, the first dielectric having a section that is a rectangular shape in which two opposing sides thereof are parallel to each other, and extends along a surface of a sample to be processed and makes an electric field strength distribution of microwaves generated from the microwave generating means substantially uniform along a surface of the sample to be processed; and  
processing means that processes the sample using plasma generated in the reaction vessel by the microwaves;  
wherein a distance  $L_{d11}$  between the two opposing sides of the first dielectric in a direction along the surface of the sample to be processed substantially satisfies the equation  $L_{d11} = n_{d11}(\lambda_1/2)$ , in which  $\lambda_1$  represents the wavelength of microwaves in the first dielectric and  $n_{d11}$  represents an integer of 1 or more.
20. (original) The plasma processing apparatus according to claim 19, further comprising:  
a slot plate that is provided between the reaction vessel and the first dielectric and in which at least one slot is formed, the slot plate maintaining or further enhancing uniformity of the electric field strength distribution of microwaves in the first dielectric; and

Appl. No. 10/707,989  
Response dated April 11, 2005  
Reply to Office Action of Jan. 11, 2005

a second dielectric that is provided between the slot plate and the reaction vessel, the second dielectric having a section that is a rectangular shape in which two opposing sides are parallel to each other, extends along a surface of a sample to be processed, and maintains or further enhances uniformity of the electric field strength distribution of microwaves supplied from the slot plate;

wherein a distance  $L_{d22}$  between the two opposing sides of the second dielectric in a direction that extends along the surface of the sample to be processed substantially satisfies the equation  $L_{d22} = n_{d22}(\lambda_2/2)$ , wherein  $\lambda_2$  represents the wavelength of microwaves in the second dielectric and  $n_{d22}$  represents an integer of 1 or more.

21. (original) The plasma processing apparatus according to claim 19, wherein

a section of the reaction vessel is a rectangular shape that extends along a surface of the sample to be processed and in which two opposing sides of the reaction vessel are parallel to each other, and a length  $L_{p2}$  of the two opposing sides of the reaction vessel substantially satisfies the equation  $L_{p2} = n_{p2}(\lambda_p/2)$ , in which  $\lambda_p$  represents the wavelength of microwaves in the reaction vessel and  $n_{p2}$  represents an integer of 1 or more.

22. (original) The plasma processing apparatus according to claim 20, wherein

a dielectric constant of the first dielectric is substantially the same as that of the second dielectric.

23. (original) The plasma processing apparatus according to claim 20, wherein

a wavelength  $\lambda_1$  of microwaves in the first dielectric and a wavelength  $\lambda_2$  of microwaves in the second dielectric substantially satisfy the equation  $\lambda_1/2 = m(1/2) \lambda_2$ , in which  $\lambda_1$  represents the wavelength of microwaves in the first dielectric,  $\lambda_2$  represents the wavelength of a microwave in the second dielectric, and  $m$  represents an integer of 1 or more.

24. (original) The plasma processing apparatus according to claim 20, wherein

a wavelength  $\lambda_1$  of microwaves in the first dielectric, a wavelength  $\lambda_2$  of microwaves in the second dielectric, and a wavelength  $\lambda_p$  of microwaves in the reaction vessel substantially satisfy the equations  $\lambda_1/2 = m(1/2) \lambda_2$  and  $\lambda_1/2 = k(1/2) \lambda_p$ , in which  $\lambda_1$  represents the wavelength of microwaves in the first dielectric,  $\lambda_2$  represents the wavelength

Appl. No. 10/707,989  
Response dated April 11, 2005  
Reply to Office Action of Jan. 11, 2005

of microwaves in the second dielectric,  $\lambda_p$  represents the wavelength of microwaves in the reaction vessel, and m, k represent an integer of 1 or more.

25. (cancelled)

26. (currently amended) ~~The plasma processing apparatus according to claim 25, wherein A~~  
plasma processing apparatus for performing plasma processing with respect to a sample to be processed in a reaction vessel, comprising:

microwave generating means for generating microwaves;  
a dielectric that is connected to the microwave generating means, is formed into a plate-like shape that extends along a surface of the sample to be processed, and makes an electric field strength distribution of the microwaves generated from the microwave generating means substantially uniform along a surface of the sample to be processed; and  
processing means that processes the sample using plasma generated in the reaction vessel by the microwaves;

wherein a plurality of introduction portions through which the microwaves are introduced from the microwave generating means to the dielectric are provided in an introduction surface that is in contact with the dielectric, and the central positions of the introduction portions are arranged on a plurality of axes on the introduction surface that extend in the same direction; and

the dielectric is formed such that a section thereof that extends along the surface of the sample to be processed is rectangular, and a distance  $L_8$  between the axes substantially satisfies the equation  $L_8 = n_{L8}(\lambda_1/2)$ , in which  $\lambda_1$  represents the wavelength of microwaves in the dielectric and  $n_{L8}$  represents an integer of 1 or more.

27. (original) The plasma processing apparatus according to claim 26, wherein

the dielectric is formed such that a section that extends along the surface of the sample to be processed is rectangular or square, and the axes extend in a direction along two opposing sides of the dielectric.

28. (original) The plasma processing apparatus according to claim 27, wherein

Appl. No. 10/707,989  
Response dated April 11, 2005  
Reply to Office Action of Jan. 11, 2005

the introduction surface is formed into a rectangular or square shape, and the axes are linearly symmetrical with respect to a central axis that extends toward the sides of the introduction surface.

29. (original) The plasma processing apparatus according to claim 28, wherein

a distance  $D_2$  between end faces of the dielectric and the axes substantially satisfies the equation  $D_2 = n_{D2}(1/4) \lambda_1$ , wherein  $\lambda_1$  represents the wavelength of microwaves in the dielectric and  $n_{D2}$  represents an integer of 1 or more.

30. (original) The plasma processing apparatus according to claim 25, wherein

a section of the dielectric that extends along the surface of the sample to be processed is rectangular, the introduction portions are alternately arranged on the two axes, and a distance  $L_9$  in an axial direction between the centers of the introduction portions alternately arranged on the two axes substantially satisfies the equation  $L_9 = n_{L9}(\lambda_1/2)$ , in which  $\lambda_1$  represents the wavelength of microwaves in the dielectric and  $n_{L9}$  represents an integer of 1 or more.

31. (original) The plasma processing apparatus according to claim 26, wherein

an H-branched waveguide is further provided between the microwave generating means and the dielectric, and the introduction surface is divided into at least two.

32. (original) The plasma processing apparatus according to claim 31, wherein

when the microwaves introduced from each of the at least two divided introduction surfaces to the dielectric have a phase identical to the other introduction surfaces, a distance  $L_{10}$  between the introduction portions in adjacent introduction surfaces substantially satisfies the equation  $L_{10} = 2n_{L10}(\lambda_1/2)$ , in which  $\lambda_1$  represents the wavelength of microwaves in the dielectric and  $n_{L10}$  represents an integer of 1 or more.

33. (original) The plasma processing apparatus according to claim 31, wherein

when the microwaves introduced from each of the at least two divided introduction surfaces to the dielectric have opposite phases, a distance  $L_{10}$  between the introduction portions in adjacent introduction surfaces substantially satisfies the equation  $L_{10} =$

Appl. No. 10/707,989  
Response dated April 11, 2005  
Reply to Office Action of Jan. 11, 2005

$(2n_{L10}+1)(\lambda_1/2)$ , in which  $\lambda_1$  represents the wavelength of microwaves in the dielectric and  $n_{L10}$  represents an integer of 1 or more.

34. (original) The plasma processing apparatus according to claim 26, wherein  
an E-branched waveguide is further provided between the microwave generating means and the dielectric, and the introduction surface is divided into at least two.

35. (original) The plasma processing apparatus according to claim 34, wherein  
when the microwaves introduced from each of the at least two divided introduction surfaces to the dielectric have identical phases, a distance  $L_{10}$  between the introduction portions in adjacent introduction surfaces substantially satisfies the equation  $L_{10} = (2n_{L10}+1)(\lambda_1/2)$ , in which  $\lambda_1$  represents the wavelength of microwaves in the dielectric and  $n_{L10}$  represents an integer of 1 or more.

36. (original) The plasma processing apparatus according to claim 34, wherein  
when the microwaves introduced from each of the at least two divided introduction surfaces to the dielectric have opposite phases, a distance  $L_{10}$  between the introduction portions in adjacent introduction surfaces substantially satisfies the equation  $L_{10} = 2n_{L10}(\lambda_1/2)$ , in which  $\lambda_1$  represents the wavelength of microwaves in the dielectric and  $n_{L10}$  represents an integer of 1 or more.

37. (cancelled)

38. (currently amended) ~~The plasma processing apparatus according to claim 37, wherein A~~  
plasma processing apparatus for performing plasma processing with respect to a sample to be processed in a reaction vessel, comprising:

microwave generating means for generating microwaves;

a slot plate that is provided between the microwave generating means and the reaction vessel and in which a plurality of slots are formed, and that makes an electric field strength distribution of the microwaves generated from the microwave generating means substantially uniform along the surface of the sample to be processed;



Appl. No. 10/707,989  
Response dated April 11, 2005  
Reply to Office Action of Jan. 11, 2005

a first dielectric that is provided between the slot plate and the reaction vessel, and maintains or further enhances uniformity of the electric field strength distribution of the microwaves supplied from the slot plate

a second dielectric that is further provided between the microwave generating means and the slot plate; and

processing means that processes the sample using plasma generated in the reaction vessel by the microwaves,

wherein a thickness of the slot plate is 1 mm or more.

39. (currently amended) The plasma processing apparatus according to claim 37 ~~38~~, wherein a thickness of the slot plate is 3 mm or more.

40. (currently amended) The plasma processing apparatus according to claim 37 ~~38~~, wherein the slots of the slot plate are rectangular, and a length  $L_{11}$  of longer sides of the slots substantially satisfies the equation  $L_{11} \geq (3/8)\lambda_A$ , in which  $\lambda_A$  represents the wavelength of microwaves introduced to the slot plate.

41. (original) The plasma processing apparatus according to claim 40, wherein the length  $L_{11}$  of the longer sides of the slots substantially satisfies the equation  $L_{11} \geq (1/2)\lambda_A$ , in which  $\lambda_A$  represents the wavelength of microwaves introduced to the slot plate.

42. (original) The plasma processing apparatus according to claim 41, wherein the length  $L_{11}$  of the longer sides of the slots substantially satisfies the equation  $L_{11} = (1/2)\lambda_A$ , in which  $\lambda_A$  represents the wavelength of microwaves introduced to the slot plate.

43. (original) The plasma processing apparatus according to claim 38, wherein sections along the surface to be processed of the sample of the first dielectric and the second dielectric are rectangular.

44. (original) The plasma processing apparatus according to claim 43, wherein the slots have substantially a same size and a same shape and are arranged in substantially the same direction, and a distance  $L_{13}$  between centers of adjacent slots

Appl. No. 10/707,989  
 Response dated April 11, 2005  
 Reply to Office Action of Jan. 11, 2005

substantially satisfies the equation  $L_{13} = n_{L13} \lambda_2$ , wherein  $\lambda_2$  represents the wavelength of microwaves in the second dielectric, and  $n_{L13}$  represents an integer of 1 or more.

45. (original) The plasma processing apparatus according to claim 43, wherein the slots have substantially the same size and same shape and are arranged in a linearly symmetrical manner with respect to either one of the axes that extend along the slot plate and orthogonal to each other, and a distance  $L_{14}$  between centers of adjacent slots substantially satisfies the equation  $L_{14} = n_{L14}(\lambda_2/2)$ , in which  $\lambda_2$  represents the wavelength of microwaves in the second dielectric, and  $n_{L14}$  represents an integer of 1 or more.

46. (currently amended) A plasma processing apparatus comprising:  
 microwave generating means;  
 a reaction vessel that is connected to the microwave generating means, in which a plasma is generated by microwaves generated from the microwave generating means;  
 an introduction channel through which a gas is supplied to the reaction vessel; and  
 at least one nozzle connecting the reaction vessel and the introduction channel,  
 wherein a transmission  $T$  of the microwaves from the reaction vessel to the nozzle substantially satisfies the equation

$$L_{g1} \geq - \frac{\ln T}{2\pi \sqrt{\left(\frac{1}{2\alpha_1}\right)^2 - \left(\frac{1}{\lambda_{308}}\right)^2}} \quad L_{g1} \geq - \frac{\ln T}{2\pi \sqrt{\left(\frac{1}{2\alpha_1}\right)^2 - \left(\frac{1}{\lambda}\right)^2}}$$

wherein  $L_{g1}$  represents the length of a nozzle in a direction in which gas therein travels,  $\alpha_1$  represents an outer diameter of the nozzle in a direction perpendicular to the direction in which the gas therein travels,  $\ln T$  represents the natural logarithm of  $T$ , and  $\lambda$  represents the wavelength of microwaves in the reaction vessel.

47. (original) The plasma processing apparatus according to claim 46, wherein a ratio of a conductance  $C_1$  of a gas in the nozzle and a conductance  $C_2$  of a gas in the introduction channel substantially satisfies the equation

$$\frac{C_2}{C_1} \geq X$$

wherein  $X$  is the number of the nozzles connected to the introduction channel.

Appl. No. 10/707,989  
Response dated April 11, 2005  
Reply to Office Action of Jan. 11, 2005

48. (original) The plasma processing apparatus according to claim 47, wherein  
the transmission T is 1% or less.

49. (original) The plasma processing apparatus according to claim 46, further comprising:  
a first dielectric that is connected to the microwave generating means, the first  
dielectric section having a rectangular section that extends along a surface of the sample to be  
processed and that makes an electric field strength distribution of the microwaves generated  
from the microwave generating means substantially uniform along the surface to be processed  
of the sample that is to be subjected to plasma processing in the reaction vessel; and  
processing means that processes the sample using the plasma.

50. (original) The plasma processing apparatus according to claim 49, further comprising:  
a slot plate that is provided below the first dielectric and in which at least one slot is  
formed, and that retains or further enhances the uniformity of the electric field strength  
distribution of the microwaves in the first dielectric; and  
a second dielectric having a rectangular section that extends along a surface of the  
sample to be processed, is provided between the slot plate and the reaction vessel, and which  
maintains or further enhances the uniformity of the electric field strength distribution of the  
microwaves supplied from the slot plate.

51. (new) The plasma processing apparatus according to claim 26, wherein the antinodes or  
nodes of the microwaves in the dielectric are positioned at each position of the axes.